Essential Model Documentation (EMD) for CMIP7

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1. Introduction

The Essential Model Documentation (EMD) is a high-level description of an earth system model (ESM).

It is intended to contain information on model formulation that may be of use to any of the diverse communities who are expected to use the model's output, whilst not being overly burdensome for the owners of the model to create.

It is not intended to contain all information about a model. More detailed model documentation than is provided by the EMD is expected to be available from the references given as part of the EMD, or will be available from further documentation that has been collated separately.

The EMD is collected for the model as a whole (section 2. Model properties) and for each of the model's components (section 3. Model component properties)

This document is intended to be a human-readable specification with initialised, but not complete, controlled vocabularies. It does not place any constraint on the tools and file-serialisation that will be required to create, store, and access EMD content. In particular, it is expected that the controlled vocabularies will need to be grown to meet the needs of the models being described.

1.1. *Application to CMIP7*

EMD is only truly useful when it is a universal resource, i.e. It has been provided for 100% of models. To ensure that this occurs, it has been agreed for its creation to be a mandatory requirement for CMIP7 participation, and the publication of a CMIP7 model's datasets to ESGF will not be possible unless EMD has been provided for that model.

For CMIP7 there will be an on-line creation tool that will provide the ability to request a new controlled vocabulary entry. Such requests will be subsequently finalised on a GitHub issue, and once accepted the new entry will be available for general use. The on-line tool will also allow documentation elements to be initialised from previously created content.

2. Model properties

Properties that provide a top-level description of the model as whole.

- **Name**
  - The name of the model.
  - For CMIP7, the name must be a registered *source_id*
  - The name may include an indication of the family, but not the particular version of the model within that family.
  - E.g. *HadGEM3-GC31-HH*
- **Family**
  - The name of the family of models that the model belongs to.
  - A family of models share much of their code bases, but may be configured in different ways (e.g. different resolutions, parameter choices, or the inclusion or not of particular model components).
  - E.g. *HadCM2*
  - E.g. *HadGEM3*
- **Components**
  - The names of the processes that are dynamically simulated by the model components.
  - Each process must be further described by the model component properties given in section 3. Model components.
  - Taken from a standardised list: 7.3. Model component process CV.
  - E.g. *atmosphere, aerosol, land surface, ocean, sea ice*
- **Description**
  - A brief, free-text scientific overview of the model.
  - The description should include a brief mention of the dynamically simulated processes given by the model **Components** property, but as much as possible should avoid duplicating information given in section 3. Model components.
- **Calendar**
  - The calendars that define which dates are permitted in the model.
  - Multiple calendars may be provided to indicate that different simulations adhere to different calendars.
  - For CMIP7, note that a given simulation's calendar is always defined in its output datasets.
  - Taken from a standardised list: 7.1. Model Calendar CV.
  - E.g. *365_day*
- **Release year**
  - The year in which this model configuration was released, or first used for published simulations.
  - E.g. *2016*
- **References**
  - References to published work for the model as a whole.
  - Each reference must include the properties described in section 4. References.

3. Model components

Properties that provide a description of individual model components.

Eight model components are defined that capture somewhat independently treatable processes: **aerosol, atmosphere, atmospheric chemistry, land surface, land ice, ocean, ocean biogeochemistry**, and **sea ice** (see section 7.2. Model component process CV). A typical climate model is composed of independently (or quasi-independently) coded components that simulate some or all of these processes.

Only model components that dynamically simulate (as opposed to being externally prescribed, such as sea surfaces temperatures in an atmosphere-only model) are described by the EMD.

Each model component must also be referenced by the model **Components** property described in section 2. Model properties.

By documenting the basic characteristics of the individual model components that simulate these processes, not only is the model formulation recorded, but it is also possible to trace their use across different climate models, and in different configurations of a single family of climate models.

- **Name**
  - The name of the model component that simulated the process
  - E.g. *BISICLES-UKESM-ISMIP6*
  - E.g. *MOSES2*
- **Family**
  - The name of the family of models that the model component belongs to.
  - A family of model components share much of their code bases, but may be configured in different ways (e.g. different resolutions, parameter choices, or the inclusion or not of particular sub-process).
  - E.g. *BISICLES*
  - *E.g. CLM4*
- **Description**
  - A scientific overview of the model component.
  - The description should summarise the key processes simulated by the model component.
  - Easy-to-answer MIP-relevant questions may have be posed, which should be addressed using free text. For instance “Are aerosols driven by emissions or concentration?” or “What is the aerosol activation scheme?”.
- **References**
  - References to published work for the model component.
  - Each reference must include the properties described in section 4. References.
- **Code base**
  - A URL (preferably for a DOI) for the source code for the model component.
  - If the source code is in a version-controlled repository (e.g. a git or svn repository) then the URL must identify a specific point in the repository’s history.
  - Set to “*private*” if not publicly available.
- **Embedded in**
  - The names of one or more other model components in which this model component is embedded.

    - See section 3.1. Embedded and Coupled model components for a definition of an embedded component.
    - Taken from a standardised list: 7.2. Model component process CV.
    - Omit when not applicable.
    - E.g. in some cases, for an aerosol model component: *atmosphere*
- **Coupled with**
    - The names one or more of other model components to which this model component is coupled.
    - See section 3.1. Embedded and Coupled model components for a definition of a coupled component.
    - Taken from a standardised list: 7.2. Model component process CV.
    - Omit when not applicable.
    - E.g. In some cases for a land ice component: *atmosphere, land surface, ocean*
- **Native horizontal grid**
    - A standardised description of the model component's horizontal grid.
    - The grid description includes the properties described in section 5.1 Native horizontal grid properties.
- **Native vertical grid**
    - A standardised description of the model component's vertical grid.
    - The grid description includes the properties described in section 5.2 Native vertical grid properties.

3.1. *Embedded and Coupled model components*

When a process is dynamically simulated with a model component that is uniquely identified by its own name and version number, it will be described as being "**coupled with**" one or more other components. On the other hand, when the process is dynamically simulated within another model component (or components) and is associated with a parent component's name and version number, it will be termed as "**embedded in**" the other component (or components).

For instance, an atmosphere component is usually "coupled with" an ocean component, and an aerosol component is often "embedded in" an atmosphere component.

This information is captured by the **Coupled with** and **Embedded in** model component properties.

4. References

The model as a whole and each model component must each have at least one reference, defined by the following properties:

- **Citation**
  - A human-readable citation for the work.
  - E.g. *Smith, R. S., Mathiot, P., Siahaan, A., Lee, V., Cornford, S. L., Gregory, J. M., et al. (2021). Coupling the U.K. Earth System model to dynamic models of the Greenland and Antarctic ice sheets. Journal of Advances in Modeling Earth Systems, 13, e2021MS002520. https://doi.org/10.1029/2021MS002520, 2023*
- **DOI**
  - The persistent identifier (DOI) used to identify the work.
  - A DOI is required for all references. A reference that does not already have a DOI (as could be the case for a technical report, for instance) must be given a one (e.g. with a service like Zenodo).
  - E.g. *https://doi.org/10.1029/2021MS002520*

5. Grid properties

Documentation of the native grid of each model component (i.e. that on which the component is integrated, rather than that on which data is output) is split into separate horizontal and vertical parts. Each part is described with a standardised specification that is based on either selections from controlled vocabularies, or the provision of numerical values. A free-text description is also available for cases where information outside of the standardised specification is useful.

There are many items in the grid descriptions, but only a subset will apply to any given grid. For instance a regular latitude-longitude grid does not need to provide any of the spectral grid truncation properties.

5.1. *Native horizontal grid properties*

The model component's native horizontal grid is described by a subset of the following properties:

- **Same as component**
  - If set to the process name of another component of this model, then the native horizontal grid of that component is assumed to apply in its entirety.
  - Taken from a standardised list: 7.2. Model component process CV.
  - If set, then no other grid native horizontal grid properties are required.
  - Most "embedded in" component grids will share the same grid as their parent component, in which case the parent component's process name should be entered here.
  - Omit when not applicable.
  - E.g. *atmosphere*
- **Descriptor**
  - A common-usage short description of horizontal type and resolution.
  - Taken from a standardised list: 7.3. Native horizontal grid Descriptor CV.
  - E.g. *N96*
- **Type**
  - The horizontal grid type, i.e. the method of distributing grid points over the sphere.
  - Taken from a standardised list: 7.4. Native horizontal grid Type CV.
  - E.g. *regular_latitude_longitude*
- **Grid mapping**
  - The name of the coordinate reference system of the horizontal coordinates.
  - Taken from a standardised list: 7.5. Native horizontal grid Grid Mapping CV.
  - E.g. *latitude_longitude*
- **Region**
  - The portion, or portions, of the globe where horizontal grid calculations are performed.
  - Taken from a standardised list: 7.6. Native horizontal grid Region CV.
  - E.g. *global*
- **Temporal refinement**
  - The grid temporal refinement.
  - Taken from a standardised list: 7.7. Native horizontal grid Temporal refinement CV.
  - E.g. *static*

- **Arrangement**
  - The grid arrangement of orthogonal physical quantities.
  - Taken from a standardised list: 7.8. Native horizontal grid Arrangement CV.
  - E.g. *Arakawa_B*
- **Description**
  - A free-text description of the grid.
  - A description is only required if there is information that is not covered by any of the other properties.
  - Omit if not required.
- **N x**
  - The number of grid cells in the X direction for mass-related quantities (as opposed to some velocity-related quantities).
  - Omit when not applicable or not constant.
  - E.g. *192*
- **N y**
  - The number of grid cells in the Y direction for mass-related quantities (as opposed to some velocity-related quantities).
  - Omit when not applicable or not constant.
  - E.g. *173*
- **N xy**
  - The number of grid cells in the horizontal plane for mass-related quantities (as opposed to some velocity-related quantities).
  - Omit when not applicable or not constant.
  - E.g. *33216*
- **N polygon**
  - The number of primal (as opposed to dual) polygons in an unstructured grid
  - Omit when not applicable or not constant.
  - E.g. *265160*
- **N side**
  - The total number of unique primal (as opposed to dual) cell sides (also known as "edges") in an unstructured grid,
  - Omit when not applicable or not constant
  - E.g. *714274*
- **N vertex**
  - The number of unique primal (as opposed to dual) vertices (also known as "nodes") in an unstructured grid,
  - Omit when not applicable or not constant.
  - E.g. *567145*
- **Truncation method**
  - The method for truncating the spherical harmonic expansion of a spectral grid
  - Taken from a standardised list: 7.9. Native horizontal grid Truncation method CV.
  - Omit when not applicable.
  - E.g. *triangular*
- **Truncation number**
  - The zonal (east-west) wave number at which a spectral grid is truncated.
  - Omit when not applicable.
  - E.g. *63*
- **Resolution range km**

- The minimum and maximum resolution (in km, and to 3 significant figures) of cells of the native grid on which mass-related quantities (as opposed to some velocity-related quantities) are calculated by the model
- It is calculated as the minimum and maximum values of d^{max} described in Appendix 2 of the CMIP6 metadata specifications document.
- A python code is available for calculating the maximum, minimum, mean and nominal resolution.
- E.g. *57.0, 290*

– **Mean resolution km**
  - The mean resolution (in km, and to 3 significant figures) of the native grid on which the mass-related quantities are carried by the model
  - It is calculated as the mean of values of d^{max} described in Appendix 2 of the CMIP6 metadata specifications document.
  - E.g. *234*

– **Nominal resolution**
  - The nominal resolution (in km) that characterises the resolution of the native grid on which mass-related quantities (as opposed to some velocity-related quantities) are calculated by the model.
  - It is calculated by applying the procedure described in Appendix 2 of the CMIP6 metadata specifications document.
  - Taken from a standardised list: 7.10. Native horizontal grid Nominal resolution CV.
  - E.g. *250 km*

5.2. *Native vertical grid properties*

The model component's native vertical grid is described by a subset of the following properties:

– **Same as component**
  - If set to the process name of another component of this model, then the grid of that component is assumed to apply in its entirety.
  - Taken from a standardised list: 7.2. Model component process CV.
  - If set, then no other native vertical grid properties are required.
  - Most "embedded in" component grids will share the same grid as their parent component, in which case the parent component's process name should be entered here.
  - Omit when not applicable.
  - E.g. *atmosphere*

– **Coordinate**
  - The coordinate type of the vertical grid.
  - Taken from a controlled vocabulary: 7.11. Native vertical grid Coordinate CV.
  - If there is no vertical dimension then the value "*none*" must be selected, and no other keywords should be set.
  - E.g. *height*

– **Description**
  - A free-text description of the vertical grid.
  - A description is only required if there is information that is not covered by any of the other properties.
  - Omit if not required.

- **N z**
  - The number of grid cells in the Z direction for mass-related quantities (as opposed to some velocity-related quantities).
  - Omit when not applicable or not constant.
  - E.g. *70*
- **N z range**
  - For vertical grids with variable resolution, the minimum and maximum number of grid cells in the Z direction for mass-related quantities (as opposed to some velocity-related quantities) at different horizontal locations.
  - Omit if the **N z** property has been set.
  - E.g. *5, 15*
- **Bottom layer thickness**
  - The thickness of the bottom model layer (i.e. the layer closest to the centre of the Earth) for mass-related quantities (as opposed to some velocity-related quantities).
  - The value should be reported as a dimensional (as opposed to parametric) quantity.
  - The value's physical units are given by the **Units** property.
  - Omit when not applicable or not constant.
  - E.g. *10*
- **Top layer thickness**
  - The thickness of the top model layer (i.e. the layer furthest away from the centre of the Earth) for mass-related quantities (as opposed to some velocity-related quantities).
  - The value should be reported as a dimensional (as opposed to parametric) quantity.
  - The value's physical units are given by the **Units** property.
  - Omit when not applicable or not constant.
  - E.g. *10*
- **Top of model**
  - The value of the upper boundary of the top model layer (i.e. the layer boundary that is furthest away from the centre of the Earth) for mass-related quantities (as opposed to some velocity-related quantities).
  - The value should be relative to the lower boundary of the bottom layer of the model, or an appropriate datum (such as mean sea level), and reported as a dimensional (as opposed to parametric) quantity.
  - The value's physical units are given by the **Units** property.
  - Omit when not applicable or not constant.
  - E.g. *85003.5*
- **Units**
  - The physical units of the **Bottom layer thickness**, **Top layer thickness**, and **Top of Model** property values.
  - Taken from a standardised list: 7.12. Native vertical grid Units CV.
  - Omit when not applicable.
  - E.g. *m*

6. Examples

Here are a limited number of model component examples, and grid-only examples, that are based on some CMIP6 models.

In the examples, ***underlined and italicised*** values are taken from the controlled vocabularies of section [7. Controlled vocabularies].

Note: These examples are for illustrative purposes only, and should not be considered as definitive descriptions of these model components.

6.1. Land Surface component

- **Name**: CLM4
- **Version**: 4
- **Family**: CLM
- **Description**: The model represents several aspects of the land surface including surface heterogeneity and consists of components or submodels related to land biogeophysics, the hydrologic cycle, biogeochemistry, human dimensions, and ecosystem dynamics. Spatial land surface heterogeneity in CLM is represented as a nested subgrid hierarchy in which grid cells are composed of multiple landunits, snow/soil columns, and PFTs. Each grid cell can have a different number of landunits, each landunit can have a different number of columns, and each column can have multiple PFTs. Biogeophysical processes are simulated for each subgrid landunit, column, and PFT independently and each subgrid unit maintains its own prognostic variables. The same atmospheric forcing is used to force all subgrid units within a grid cell. The surface variables and fluxes required by the atmosphere are obtained by averaging the subgrid quantities weighted by their fractional areas.
- **References**
  - **Citation**: Oleson K, Lawrence D, Gordon B, Flanner M, Kluzek E, Peter J, Levis S, Swenson S, Thornton P, and Feddema J, Technical description of version 4.0 of the Community Land Model (CLM), 2010, http://www.cesm.ucar.edu/models/cesm1.0/clm/CLM4_Tech_Note.pdf, 2023
- **Embedded in**: *atmosphere*
- **Native horizontal grid**
  - **Same as component**: *atmosphere*
- **Native vertical grid**
  - **Coordinate**: *depth*
  - **Description**: Vegetated, wetland, and glacier landunits have 15 vertical layers. Lakes have 10 layers. Snow can have up to 5 layers.

6.2. Land Ice component

- **Name**: BISICLES-UKESM-ISMIP6-1.0
- **Version**: 1.0
- **Family**: BISICLES
- **Description**: UniCiCles (Unified Model-CISM-BISICLES) is a package combining BISICLES with an interface that obtains boundary conditions from Unified Model or

JULES data, using code derived from the Glint interface of the Glimmer-CISM ISM. BISICLES uses the adaptive-mesh Chombo libraries. All cells in the mesh are rectangles that may be recursively refined by subdivision into four smaller cells with the same aspect ratio. The configuration of BISICLES approximates the momentum equations using the ”shelfy-stream” approximation with simplified vertical shear strains included in the effective viscosity, often referred to as SSA*. Basal traction is set to zero beneath floating ice and modelled using power laws beneath grounded ice. Greenland ice seheet uses a linear drag law everywhere while AIS uses a cubic law far upstream from the grounding line, which tends to a Coulomb friction law near the grounding line.

- **References**
  - **Citation**: Smith, R. S., Mathiot, P., Siahaan, A., Lee, V., Cornford, S. L., Gregory, J. M., et al. (2021). Coupling the U.K. Earth System model to dynamic models of the Greenland and Antarctic ice sheets. Journal of Advances in Modeling Earth Systems, 13, e2021MS002520. https://doi.org/10.1029/2021MS002520, 2023
  - **DOI**: https://doi.org/10.1029/2021MS002520
- **Coupled with**: *atmosphere*, *land surface*, *ocean*
- **Native horizontal grid**
  - **Type**: *plane_projection_grid*
  - **Grid mapping**: *polar_stereographic*
  - **Region**: *greenland, antarctica*
  - **Arrangement**: *arakawa_A*
  - **Temporal refinement**: *adaptive*
  - **Description**: Greenland ice sheet (GrIS) is modelled with 9.6 km square base cells that may subdivide to 1.2 km and Antarctic ice sheet (AIS) with 8 km that may subdivide to 2 km. The meshes are updated every 8 timesteps for GrIS and 4 for AIS allowing the resolution to evolve with the ice dynamics.
  - **Resolution range km**: 1.7, 13.6
  - **Mean range km**: 3.67
  - **Nominal resolution**: *5 km*
- **Native vertical grid**
  - **Coordinate**: *land_ice_sigma_coordinate*
  - **N z**: 10

6.3. Grid: Regular latitude-longitude/atmosphere_hybrid_height_coordinate

- **Native horizontal grid**
  - **Descriptor:** *N216*
  - **Type:** *regular_latitude_longitude*
  - **Grid mapping:** *latitude_longitude*
  - **Region:** *global*
  - **Arrangement:** *arakawa_C*
  - **Temporal refinement:** *static*
  - **N xy:** 139968
  - **N x:** 432
  - **N y:** 324
  - **Resolution range km**: 75, 140
  - **Mean resolution km**: 95.8
  - **Nominal resolution**: *100 km*

- **Native vertical grid**
  - **Coordinate**: *atmosphere_hybrid_height_coordinate*
  - **N z**: 85
  - **Top of model**: 84763.34
  - **Units**: *m*

6.4. *Grid: Tripolar ocean*

- **Native horizontal grid**
  - **Descriptor:** *eORCA025*
  - **Type:** *tripolar*
  - **Grid mapping:** *latitude_longitude*
  - **Region:** *global_ocean*
  - **Arrangement:** *arakawa_C*
  - **Temporal refinement:** *static*
  - **N xy:** 1725200
  - **N x:** 1440
  - **N y:** 1205
  - **Resolution range km**: 15, 60
  - **Mean resolution km**: 32.4
  - **Nominal resolution**: *25 km*
- **Native vertical grid**
  - **Coordinate**: *ocean_s_coordinate*
  - **N z**: 75
  - **Top layer thickness**: 1.5
  - **Units**: *m*

6.5. *Grid: Reduced Gaussian*

- **Native horizontal grid**
  - **Descriptor:** *T127*
  - **Type:** *reduced_gaussian*
  - **Grid mapping:** *latitude_longitude*
  - **Region:** *global*
  - **Arrangement:** *arakawa_B*
  - **Temporal refinement:** *static*
  - **Description**: Gaussian Reduced with 256 grid points per latitude circle between 30 degrees north and 30 degrees south, reducing to 20 grid points per latitude circle at 88.9 degrees north and 88.9 degrees south.
  - **N xy:** 24572
  - **N y:** 128
  - **Truncation method**: *triangular*
  - **Truncation number**: 127
  - **Resolution range km**: 34, 140
  - **Mean resolution km**: 123
  - **Nominal resolution**: *100 km*
- **Native vertical grid**
  - **Coordinate**: *atmosphere_hybrid_sigma_pressure_coordinate*
  - **N z**: 91

- **Top of model**: 1500
- **Units**: *Pa*

6.6. *Grid: Unstructured grid*

- **Native horizontal grid**
  - **Descriptor:** *oEC60to30*
  - **Type:** *unstructured_polygon*
  - **Grid mapping:** *latitude_longitude*
  - **Region:** *global_ocean*
  - **Arrangement:** *arakawa_C*
  - **Temporal refinement:** *static*
  - **Description**: Unstructured mesh created using Spherical Centroidal Voronoi Tessellations.
  - **N polygon:** 235160
  - **N side:** 714274
  - **Resolution range km**: 30, 60
  - **Mean resolution km**: 45.7
  - **Nominal resolution**: *50 km*

7. Controlled vocabularies

Many EMD property values are restricted to selections from controlled vocabularies, i.e. standardised lists which contain all possible values.

It is known that some of these controlled vocabularies are not complete, because it is not known in advance what is required for every model.

For CMIP7, the EMD on-line creation tool will provide the ability to request a new controlled vocabulary entry, which will be subsequently finalised on a GitHub issue. Once accepted, the new entry will be available for general use.

7.1. *Model **Calendar** CV*

The type of calendar used by the model. The calendar names are all CF calendar names with the same definition.

Used by the model **Calendar** property.

- **standard**
  - *A mixed Gregorian/Julian calendar which is Gregorian after 1582-10-15, and Julian before.*
- **proleptic_gregorian**
  - *A calendar with the Gregorian rules for leap-years extended to dates before 1582-10-15.*
- **julian**
  - *The Julian calendar, in which a year is a leap year if it is divisible by 4, even if it is also divisible by 100.*
- **utc**
  - *A Gregorian calendar with leap seconds as prescribed by UTC.*
- **tai**
  - *A Gregorian calendar without leap seconds based on International Atomic Time.*
- **360_day**
  - *A calendar in which all years are 360 days, and divided into 30 day months.*
- **365_day**
  - *A calendar with no leap years, i.e. all years are 365 days long.*
- **366_day**
  - *A calendar in which every year is a leap year, i.e. all years are 366 days long.*
- **none**
  - *No calendar.*

7.2. *Model component **process** CV*

The processes that are dynamically simulated by the model components. See 3. Model component properties for more details.

Used by the model **Components**; model component **Embedded in** and **Coupled with** properties; and the native horizontal and vertical grid **Same as component** properties.

- **aerosol**
- **atmosphere**

- **atmospheric chemistry**
- **land surface**
- **land ice**
- **ocean**
- **ocean biogeochemistry**
- **sea ice**

7.3. *Native horizontal grid* ***Descriptor*** *CV*

Native horizontal grid descriptor, i.e. a common-usage short description of horizontal grid type and resolution.

Used by the native horizontal grid **Descriptor** property.

- **N48**
  - *A regular latitude-longitude grid with 96 east-west points.*
- **N96**
  - *A regular latitude-longitude grid with 192 east-west points.*
- **N216**
  - *A regular latitude-longitude grid with 432 east-west points.*
- **N512**
  - *A regular latitude-longitude grid with 1024 east-west points.*
- **N1280**
  - *A regular latitude-longitude grid with 2560 east-west points.*
- **ORCA2**
  - *The ORCA tripolar ocean grid at 2 degree resolution.*
- **eORCA2**
  - *The ORCA tripolar ocean grid at 2 degree resolution extended to fully include oceans under ice shelves*.
- **ORCA1**
  - *The ORCA tripolar ocean grid at 1 degree resolution.*
- **eORCA1**
  - *The ORCA tripolar ocean grid at 1 degree resolution extended to fully include oceans under ice shelves*.
- **ORCA025**
  - *The ORCA tripolar ocean grid at 0.25 degree resolution.*
- **eORCA025**
  - *The ORCA tripolar ocean grid at 0.25 degree resolution extended to fully include oceans under ice shelves*.
- **ORCA012**
  - *The ORCA tripolar ocean grid at 0.08 degree resolution.*
- **eORCA012**
  - *The ORCA tripolar ocean grid at 0.08 degree resolution extended to fully include oceans under ice shelves*.
- **T42**
  - *A spectral Gaussian grid with triangular truncation number 42*.
- **T63**
  - *A spectral Gaussian grid with triangular truncation number 63.*
- **T85**
  - *A spectral Gaussian grid with triangular truncation number 85.*

- **T106**
  - *A spectral Gaussian grid with triangular truncation number 106.*
- **T127**
  - *A spectral Gaussian grid with triangular truncation number 127.*
- **T255**
  - *A spectral Gaussian grid with triangular truncation number 255.*
- **TL95**
  - *A linear spectral Gaussian grid with triangular truncation number 95.*
- **TL159**
  - *A linear spectral Gaussian grid with triangular truncation number 159*.
- **TL255**
  - *A linear spectral Gaussian grid with triangular truncation number 255*.
- **TL319**
  - *A linear spectral Gaussian grid with triangular truncation number 319.*
- **TL511**
  - *A linear spectral Gaussian grid with triangular truncation number 511.*
- **TL959**
  - *A linear spectral Gaussian grid with triangular truncation number 959.*
- **TL1279**
  - *A linear spectral Gaussian grid with triangular truncation number 1279.*
- **Tco199**
  - *A cubic-octahedral spectral reduced Gaussian grid with triangular truncation number 199.*
- **Tco399**
  - *A cubic-octahedral spectral reduced Gaussian grid with triangular truncation number 399*.
- **R30**
  - *A rhomboidal spectral Gaussian grid with truncation number 30.*
- **C96**
  - *A cubed-sphere grid with $96 \times 96 \times 6 = 55296$ points.*

7.4. *Native horizontal grid **Type** CV*

Native horizontal grid type, i.e. methods for distributing grid points over the sphere.

Used by the native horizontal grid **Type** property.

- **regular_latitude_longitude**
  - *A rectilinear latitude-longitude grid with evenly spaced latitude points and evenly spaced longitude points.*
- **regular_gaussian**
  - *A Gaussian grid for which the number of longitudinal points is constant for each latitude.*
- **reduced_gaussian**
  - *A Gaussian grid for which the number of longitudinal points is reduced as the poles are approached.*
- **spectral_gaussian**
  - *A grid based on the transformation from spectral space to a reduced or non-reduced Gaussian grid.*
- **spectral_reduced_gaussian**

- *A grid based on the transformation from spectral space to a reduced Gaussian grid.*

- **linear_spectral_gaussian**
  - *A spectral Gaussian grid for which the smallest spectral wavelength is represented by 2 grid points.*
- **quadratic_spectral_gaussian**
  - *A spectral Gaussian grid for which the smallest spectral wavelength is represented by 3 grid points.*
- **cubic_octahedral_spectral_reduced_gaussian**
  - *A spectral reduced Gaussian grid for which the smallest spectral wavelength is represented by 4 grid points, and which uses an octahedron-based method to reduce the number of grid points towards the poles.*
- **rotated_pole**
  - *A regular latitude-longitude grid that is rotated to define a different north pole location.*
- **stretched**
  - *A grid with higher resolution concentrated over an area of interest, at the expense of lower resolution elsewhere.*
- **displaced_pole**
  - *An ocean grid whose poles are not antipodean, typically with the northern pole displaced to lie over land.*
- **tripolar**
  - *A global curvilinear ocean grid with a southern pole and two northern poles all placed over land.*
- **cubed_sphere**
  - *The spherical surface is defined as six coupled "square" regions.*
- **icosahedral_geodesic**
  - *A grid that uses triangular tiles based on the subdivision of an icosahedron.*
- **icosahedral_geodesic_dual**
  - *A grid that uses hexagonal and pentagonal tiles and is the dual of an icosahedral_geodesic grid.*
- **yin_yang**
  - *Two overlapping grid patches.*
- **unstructured_triangular**
  - *An unstructured mesh consisting solely of triangles.*
- **unstructured_polygonal**
  - *An unstructured mesh consisting of arbitrary polygons.*
- **plane_projection**
  - *Any transformation employed to represent the spherical surface of the globe on a plane*
- **none**
  - *There is no horizontal grid.*

7.5. Native horizontal grid ***Grid Mapping*** *CV*

Native horizontal grid mapping, i.e. the coordinate reference system of the grid. The grid mappings are all CF grid mapping names with the same definitions.

Used by the native horizontal grid **Grid Mapping** property.

- **albers_conical_equal_area**
- **azimuthal_equidistant**
- **geostationary**
- **lambert_azimuthal_equal_area**
- **lambert_conformal_conic**
- **lambert_cylindrical_equal_area**
- **latitude_longitude**
- **orthographic**
- **polar_stereographic**
- **rotated_latitude_longitude**
- **sinusoidal**
- **stereographic**
- **transverse_mercator**
- **vertical_perspective**

7.6. Native horizontal grid **Region** CV

Native horizontal grid region types, i.e. the portion of the globe where horizontal grid calculations are performed. The region types are CF standardised regions (except where indicated) with the same definitions.

Used by the native horizontal grid **Region** property.

- **global**
  - *The entire land and ocean surface of the Earth.*
- **global_land**
  - *The entire land surface of the Earth.*
- **global_ocean**
  - *The entire ocean surface of the Earth.*
- **antarctica**
  - *The Antarctic ice sheet.*
- **greenland**
  - *The Greenland ice sheet.*
- **limited_area**
  - *(Not a CF region.) Any contiguous part of the surface of the Earth.*

7.7. Native horizontal grid **Temporal refinement** CV

Native horizontal grid temporal refinement types, i.e. How the distribution of grid cells varies with time.

Used by the native horizontal grid **Temporal refinement** property.

- **static**
  - *The total number of grid points stays constant during the model run and there is no grid refinement, i.e. the grid is held fixed.*
- **dynamically_stretched**
  - *The total number of grid points stays constant, but grid points can be dynamically relocated.*
- **adaptive**

   - *The total number of grid points varies during the model run. The grid is refined locally when important physical processes occur that need additional grid resolution, and coarsened when the additional resolution is no longer needed.*

7.8. Native horizontal grid **Arrangement** CV

Native horizontal grid Arakawa arrangement types. The Arakawa grid arrangement describes how orthogonal physical quantities (especially mass-related and velocity-related quantities) are represented and computed on the grid. See, for example, Collins et al. (2013) for a description of each grid type.

Used by the native horizontal grid **Arrangement** property.

- **arakawa_A**
- **arakawa_B**
- **arakawa_C**
- **arakawa_D**
- **arakawa_E**

7.9. Native horizontal grid **Truncation method** CV

Native horizontal grid methods for truncating the spherical harmonic expansion of a spectral grid.

Used by the native horizontal grid **truncation method** property.

- **triangular**
   - *Triangular truncation.*
- **rhomboidal**
   - *Rhomboidal truncation.*

7.10. Native horizontal grid **Nominal resolution** CV

Native horizontal grid nominal resolution. The nominal resolution (in km) characterises the resolution of the native grid on which the mass-related quantities (as opposed to some velocity-related quantities) are calculated by the model component. It is derived by applying the procedure described in Appendix 2 of the CMIP6 metadata specifications document.

Used by the native horizontal grid **Nominal resolution** property.

- **0.5 km**
- **1 km**
- **2.5 km**
- **5 km**
- **10 km**
- **25 km**
- **50 km**
- **100 km**
- **250 km**
- **500 km**
- **1000 km**

- **2500 km**
- **5000 km**
- **10000 km**

7.11. *Native vertical grid* ***Coordinate*** *CV*

Native vertical grid coordinate type. The coordinate types are all CF standard names (except where indicated) with the same definitions.

Used by the native vertical grid **Coordinate** property.

- **none**
  - *(Not a standard name)There is no vertical dimension.*
- **height**
  - *Height is the vertical distance above the earth's surface.*
- **geopotential_height**
  - *Geopotential height is the geopotential divided by the standard acceleration due to gravity.*
- **air_pressure**
  - *Air pressure is the pressure that exists in the medium of air.*
- **air_potential_temperature**
  - *Air potential temperature is the temperature a parcel of air would have if moved dry adiabatically to a standard pressure.*
- **atmosphere_ln_pressure_coordinate**
  - *Parametric atmosphere natural log pressure coordinate.*
- **atmosphere_sigma_coordinate**
  - *Parametric atmosphere sigma coordinate.*
- **atmosphere_hybrid_sigma_pressure_coordinate**
  - *Parametric atmosphere hybrid sigma pressure coordinate.*
- **atmosphere_hybrid_height_coordinate**
  - *Parametric atmosphere hybrid height coordinate.*
- **atmosphere_sleve_coordinate**
  - *Parametric atmosphere smooth vertical level coordinate.*
- **depth**
  - *Depth is the vertical distance below the earth's surface.*
- **sea_water_pressure**
  - *Sea water pressure is the pressure that exists in the medium of sea water.*
- **sea_water_potential_temperature**
  - *Sea water potential temperature is the temperature a parcel of sea water would have if moved adiabatically to sea level pressure.*
- **ocean_sigma_coordinate**
  - *Parametric ocean sigma coordinate.*
- **ocean_s_coordinate**
  - *Parametric ocean s-coordinate.*
- **ocean_s_coordinate_g1**
  - *Parametric ocean s-coordinate, generic form 1.*
- **ocean_s_coordinate_g2**
  - *Parametric ocean s-coordinate, generic form 2.*
- **ocean_sigma_z_coordinate**
  - *Parametric ocean sigma over z coordinate.*

- **ocean_double_sigma_coordinate**
    - *Parametric ocean double sigma coordinate.*
- **land_ice_sigma_coordinate**
    - *Land ice (glaciers, ice-caps and ice-sheets resting on bedrock and also includes ice-shelves) sigma coordinate.*
- ***z****
    - *(Not a standard name) The z* coordinate of Adcroft and Campin (2004).*

7.12. *Native vertical grid **Units** CV*

Native vertical grid units of the top level boundary or top layer thickness value.

Used by the native vertical grid **Units** property.

- **m**
- **Pa**
- **K**

9. References

Adcroft, Alistair & Campin, Jean-Michel. (2004). **Rescaled height coordinates for accurate representation of free-surface flows in ocean circulation models**. Ocean Modelling. 7. 269-284. 10.1016/j.ocemod.2003.09.003

S. N. Collins, R. S. James, P. Ray, K. Chen, A. Lassman, and J. Brownlee: **Grids in Numerical Weather and Climate Models', Climate Change and Regional/Local Responses**. InTech, May 22, 2013. doi: http://dx.doi.org/10.5772/55922

Eaton, B., Gregory, J., Drach, B., Taylor, K., Hankin, S., Caron, J., Signell, R., Bentley, P., Rappa, G., Höck, H., Pamment, A., Juckes, M., Raspaud, M., Blower, J., Horne, R., Whiteaker, T., Blodgett, D., Zender, C., Lee, D., … Bartholomew, S. L. (2024). **NetCDF Climate and Forecast (CF) Metadata Conventions**. CF Community. https://doi.org/10.5281/zenodo.14274886

Eyring, V., Bony, S., Meehl, G. A., Senior, C. A., Stevens, B., Stouffer, R. J., and Taylor, K. E.: **Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization**, Geosci. Model Dev., 9, 1937–1958, https://doi.org/10.5194/gmd-9-1937-2016, 2016

Karl E. Taylor, Martin Juckes, V. Balaji, Luca Cinquini, Sébastien Denvil, Paul J. Durack, Mark Elkington, Eric Guilyardi, Slava Kharin, Michael Lautenschlager, Bryan Lawrence, Denis Nadeau, and Martina Stockhause: **CMIP6 Global Attributes, DRS, Filenames, Directory Structure, and CVs**. https://wcrp-cmip.github.io/WGCM_Infrastructure_Panel/Papers/CMIP6_global_attributes_filenames_CVs_v6.2.7.pdf

CF calendars: http://cfconventions.org/cf-conventions/cf-conventions.html#calendar

CF standard name table: http://cfconventions.org/Data/cf-standard-names/current/build/cf-standard-name-table.html

CF grid mappings: http://cfconventions.org/cf-conventions/cf-conventions.html#appendix-grid-mappings

CF standardised region list: http://cfconventions.org/Data/standardized-region-list/standardized-region-list.current.html

Algorithms for defining the nominal resolution: https://docs.google.com/document/d/13t8vtzLYnOAPS_aI1mPkKdrxjR6VysfHmEICLjiLSKE

Python code for calculating the nominal resolution: https://pcmdi.github.io/nominal_resolution/html/index.html